SILURIA.

CHAPTER I.

INTRODUCTION — ORIGINAL SILURIAN RESEARCHES. — DESIGN OF THIS WORK.

THE earliest condition of the earth is necessarily the darkest period of its geological history. The favourite hypothesis concerning the origin of the planet, founded on astronomical and physical analogies, is, that it assumed the form of a flattened spheroid from rotation on its axis when in a fluid state. Reasoning upon this idea, and looking to the structure of those rocks which either lie at great depths or have been extruded from beneath, the geologist has inferred that the crystalline masses, including granites which issued out from below all other rocks, and constitute possibly their existing substratum, were at one time in a molten state. The theory of a central heat, at first sufficiently intense to maintain the whole terrestrial mass in a state of fusion, but subsequently so far dissipated by radiation into space, as to allow the superficial portion to become solid, has been adopted by the greater number of philosophers who have grappled with the difficult problem of the first conditions of our planet. Most of them likewise have believed that all the great outbursts of igneous matter, by which the crust has been penetrated and its surface diversified, were merely outward signs of the continued internal activity of that primordial heat, now much repressed

by the accumulations of ages, and of which our present volcanoes are feeble indications. If, then, the mathematician has correctly explained the causes of the shape of the globe, the geologist confirms his views when, examining into the nature of its oldest massive crystalline rocks, he sees in them clear proofs of the effects of intense heat. This original crust of the earth was subsequently, we may believe, broken up by protruded masses, which, issuing in a melted condition, constituted the axes and centres of mountain chains. Each great igneous eruption gave out substances that became, on cooling, solid rocks, which, when raised into the atmosphere, constituted lands that were exposed to innumerable wasting agencies; and thus afforded materials to be spread out as deposits upon the shores and bed of the ocean. In these hypothetical views concerning the production of the earliest sediments formed under water, we seem to reach a primary source; and once admitting that large superficial areas were originally occupied by igneous rocks, we have in them a basis from which the first sedimentary materials were obtained.

The earlier eruptions having necessarily occasioned elevations at some points and collapses or depressions at others, such changes of outline, aided by the grinding action of water, would occasion the formation of bands of sediment, which, adapting themselves to the inequalities of the surface, must have been of unequal dimensions in different parts of their range. In this way we may imagine how, by a repetition of the processes of elevation and denudation, the earliest exterior rugosities of the earth would be in some places increased, while in others they would be placed beyond the influence of sedimentary accumulation. May we not also infer, that the numerous molten rocks of great dimensions which were suddenly evolved from the interior at subsequent periods, must have made enormous additions to the solid crust of the earth, and have constituted grand sources for the augmentation of new strata?

Turning from the igneous rocks to crystalline stratified deposits,

we now know that a great portion of the micaceous schists, chloritic and quartzose rocks, clay-slates, and limestones, once called primary, were of later origin. Many of these are nothing more than subaqueous sediments of various epochs, which have been altered and crystallized at periods long subsequent to their accumulation. This inference has been deduced from positive observation. Rocks, for example, have been tracked from the districts where they are crystalline, to spots where the mechanical and subaqueous origin of the beds is obvious, and from the latter to localities where the same strata are wholly unchanged, and contain organic remains. Transitions are thus seen from compact quartz rock, in which the grains of silica are scarcely discoverable with a powerful lens, to strata in which the sandy, gritty, and pebbly particles bespeak clearly that the whole range was originally accumulated under water. Other passages occur from crystalline, chloritic, and micaceous schists, to those clay-slates which are little more than consolidated mud, and from crystalline marble to common earthy limestone, in which organic remains abound. These and similar metamorphoses embrace the consideration of changes, like those, for example, by which ordinary limestone has been converted into dolomite and sulphate of lime or gypsum, or shale into mica-schist, as is seen in the secondary and tertiary rocks of the Alps.*

Elementary works will have, indeed, informed the student, that such changes of the original sediment have been generally accounted for by the influence of great heat proceeding from the interior of the earth, and which at different former periods manifested its power in the eruption of granites, syenites, porphyries, greenstones, and other substances formed by fusion. Let it, however, be understood, that the prodigious extent to which the metamorphism of the original strata has been carried in mountain-chains, and at different periods through all formations, though often

* See Alps, Apennines, &c. Quart. Journ. Geol. Soc. Lond. vol. v. p. 157. *et seq.*

probably connected with such igneous outbursts, must have resulted from a far mightier agency than that which was productive of the mere eruptions of molten matter or igneous rocks. The latter are, in fact, but partial excrescences in the vast spread of the stratified crystalline rocks, — symptoms only of the grand changes which resulted from deep-seated causes; probably from the combination of heat, steam, and electricity, acting together with an intensity very powerful in former periods.

Processes now going on in nature on a small scale, or imitated artificially by man, may enable us to comprehend imperfectly in what manner some of these infinitely grander ancient metamorphoses were effected; and the experimental science of chemistry, when more extensively applied to the analysis of rocks, will, it is hoped, some day reveal still more important truths in this, which is still one of the most obscure points in the range of geological phenomena.

But speculations on such physical operations as those which have affected the surface of the earth, are not here called for. At all events, the earliest of the phenomena, with which alone we are at present concerned, or the first formation of the known crust of the planet, belongs to a period in which no definite order,— still less any trace of life,— has been deciphered by human labour.*

The design of this work is much more attainable. Its aim is to mark the most ancient strata in which the proofs of sedimentary or aqueous action are still visible,—to note the geological position of those beds which in various countries offer the first ascertained signs of life, and to develop the succession of deposits, where not obscured by metamorphism, that belong to such protozoic zones. In thus adhering only to subjects capable of being investigated, it will

* The reader who desires to study the laws by which the superficial temperature of the earth has been regulated in the immensely long subsequent geological periods, will find them well explained in the profound essay of Mr. W. Hopkins, "On the causes of changes of *climate* at different geological periods," Quart. Journ. Geol. Soc. Lond. vol. viii. p. 56.

be seen, that geology, modern as she is among the sciences, has revealed to us, that during cycles long anterior to the creation of the human race, and while the surface of the globe was passing from one condition to another, whole races of animals — each group adapted to the physical conditions in which they lived — were successively created and exterminated. It is to the first stages only of this grand and long series of former accumulations, and to the creatures entombed in them, that attention is now directed.

The convictions at which I have arrived being the result of many years of research, I have been urged by numerous friends to give a condensed, and, as far as is practicable, a popular view of the oldest sedimentary rocks and of their chief organic remains, and thus to throw into one moderate-sized volume the essence of my large works *, as sustained by the publications of many other authors.

Geologists are now pretty generally agreed, that the oldest organic remains which are traceable, pertain to the lower division of the rocks termed Silurian; but before any description of these ancient deposits, or of those preceding them, is given, a few words are required, in explanation of the researches by which our acquaintance with the earliest vestiges of life and order in the protozoic world has been attained.

One of the chief steps which led to the present classification, as admitted by my contemporaries, was the establishment of the 'Silurian System' of rocks and their imbedded fossils. Before the labours which terminated in the publication of the work so named, no one had unravelled the detailed sequence and characteristic fossils of any strata of a higher antiquity than the Old Red Sandstone; and even that formation was only known to be the natural base of the Carboniferous or Mountain limestone, and to contain a few undescribed fossil fishes. Not only were the relations and contents of all

* See Silurian System, Murchison, 1839; and Russia in Europe and the Ural Mountains, by Murchison, de Verneuil, and de Keyserling (J. Murray, 1845).

the inferior strata undefined, but even many rocks which are now known to be younger than the Silurian, were then considered to be of much more remote antiquity. No one had then surmised, that the great series of hard slates with limestones and fossils, which have since been termed Devonian, is an equivalent of the Old Red Sandstone, and younger than, as well as distinct from, the deposits of the still older Silurian era. On the contrary, British authorities believed (and I was myself so taught) that the schistose and subcrystalline rocks of Devonshire and Cornwall were about the most ancient of the vast undigested heaps of greywacke. In short, the best geologists* of my early days were accustomed to leave off with such rocks, as constituting obscure heaps of sediment, in and below which no succession of "strata as identified by their fossils" could be detected. The result of research, however, has been the elimination of several well-defined groups, all of which were formerly merged in the unmeaning German term 'grauwacke.' (See Chap. 14.)

Desirous of throwing light on this dark subject, I consulted my valued friend and instructor, Dr. Buckland, as to the region most likely to afford evidences of order, and by his advice I first explored, in 1831, the banks of the Wye between Hay and Builth. Discovering a considerable tract in Hereford, Radnor, and Shropshire, wherein large masses of grey-coloured strata rise out from beneath the Old Red Sandstone, and contain fossils differing from any which were known in the superior deposits, I began to classify these rocks. After four years of consecutive labour, I assigned to them (1835) the name Silurian, deriving it from the portion of England and Wales, in which the successive formations are clearly displayed, and wherein an ancient British people, the Silures, under their king Caradoc (Caractacus), had opposed a long and

* See those classical works, the first Geological Map of Mr. Greenough, and the Geology of England and Wales, by the Rev. W. D. Conybeare.

valorous resistance to the Romans. Having first, in the year 1833, separated these deposits* into four formations, and shown that each is characterized by peculiar organic remains, I next divided them (1834, 1835) into a lower and upper group, both of which I hoped would be found applicable to wide regions of the earth. After eight years of labour in the field and closet, the proofs of the truth of those views were more fully published in the work entitled the 'Silurian System' (1839).

During my early researches, it was shown that the lowest of these (1833) fossil-bearing strata reposed, in the west of Shropshire, on a very thick accumulation of still older sediment, as exposed in the ridge of the Stiper Stones, and the Longmynd mountain; and the strata of the latter not offering a vestige of former life, they were consequently termed unfossiliferous greywacke.

At that time it was also supposed, that the contiguous slaty region of North Wales, then under the examination of Professor Sedgwick, consisted of rocks, in part fossiliferous, and of an enormous thickness, which rose up, according to my friend and fellow labourer, from beneath my Silurian types. Hence, another term, or that of Cambrian, was afterwards, or in the year 1836, applied to masses supposed to be inferior, before their true relations to the Silurian strata of Shropshire and Montgomeryshire had been ascertained. This assumed inferiority of position in the slaty rocks of North Wales being considered a fixed point, it was naturally thought, that such lower formations, the fossils of which were then undescribed, would be found to contain a set of organic remains,

* For the first tabular view of these four formations, the bottom one resting on the unfossiliferous greywacke of the Longmynd, see Proceedings Geol. Soc. Lond. vol. ii. p. 11., Jan. 1834. The characteristic fossil species were even then enumerated, and hence the classification which is now sustained is essentially twenty years old. It had even been previously stated by me, that the lowest known fossil-bearing formation, or the '*black trilobite schists and flags of Llandeilo, probably exceeded in thickness any of the superior groups.*'—Proc. Geol. Soc. vol. i. p. 476. 1833.

differing as a whole from those of my classified and published Silurian system. With other geologists, therefore, I waited for the production of the fossils which might typify such supposed older sediments; for in obtaining all the knowledge I had then acquired, by receding from upper strata whose contents were known, to lower and previously unknown rocks, I had invariably found that the latter were characterized by many distinct and new organisms. This fact, which had been first established in the tertiary and secondary deposits, was thus proved to be universally applicable by the occurrence of similar distinctions in the Carboniferous, Old Red, and Silurian rocks.

It was, however, in vain that we looked to the production of a peculiar type of life from the 'Cambrian' rocks. Silurian fossils were alone found in them; and the reason has since become manifest. The labours of many competent observers in the last fifteen years have proved that these rocks are not inferior in position, as they were supposed to be, to the lowest stratified rocks of my Silurian region of Shropshire and the adjacent parts of Montgomeryshire, *but are merely extensions of the same strata;* and hence the looked-for geological and zoological distinctions could never have been realized. In the following chapters it will be shown how Sir H. De la Beche, Professors Ramsay and E. Forbes, with Mr. Salter, and other geologists and palæontologists, have demonstrated, that the fossil-bearing rocks of North Wales are both in their order and contents the absolute equivalents of the chief mass of the strata which had been described and named by me 'Lower Silurian' in Shropshire and Montgomeryshire. These Government geologists have used my nomenclature in all their works relating to North Wales, and have, in short, determined the question physically as well as zoologically.*

But although in 1839, when my first work was completed, I held,

* See also Phillips, on the Malvern and Abberley Hills.—Memoirs, Geol. Surv. Vol. ii. Pt. 1. 1848.

in common with Professor Sedgwick, the erroneous idea of the infra-Silurian position of the rocks of North Wales, I soon saw reason to abandon that view, and to adopt (in the year 1841) the opinion which I have subsequently maintained. Thirteen years have elapsed since I was persuaded that the view I then took must be adhered to; first, because it had been ascertained, that in Scandinavia, Russia, Bohemia, and other countries, the oldest traces of former life were the same as the lower Silurian types of the British Isles; — and next, because many of the fossils figured in my work as Lower Silurian had been detected in the slates of Snowdon, which were then considered to lie near the bottom of the so-called 'Cambrian rocks.'

The leading object, therefore, of the present work is, I repeat, to bring out the 'Silurian System,' not as a mere abridgment of its original form; but such as it finally became in the year 1849, when it was honoured with the highest distinction which the Royal Society bestows*, and what it has proved to be, with the geographical and other additions made to it by the government surveyors at home, and by numerous geologists in other countries.

In extending my own researches to various distant lands, I found that as the true base of all rocks containing fossil remains was clear in Scandinavia, Russia, and Bohemia, and as the same fact was announced from North America, it was no longer difficult to describe the whole organic series *from a beginning*, and thus to record the succession of animals from their earliest known developments. In a word, as chroniclers of lost races, my associates and myself were enabled to register in our 'Russia and the Ural Mountains,' the types of former creatures from their apparent dawn. To the first chapters of that work, the reader is referred as fully explanatory of views which are here reiterated.† Then it was,

* The Copley Medal.

† The reader who desires to consult the documents which explain how my induction was arrived at, is referred to a memoir entitled, "On the meaning at-

that positive proofs, derived from a wide field of observation, enabled us to commence geological history, with an account of the entombment of the earliest animals recognizable in the crust of the globe; and also to indicate the successive conditions which prevailed upon the surface, in a long series of ages, and during the many changes of outline which preceded the present state of the planet. Then it was, that looking to the whole history of former life, as exhibited in the strata, it was demonstrated from phenomena in one great empire alone (as had to a great extent been shown in Britain), that during the formation of the sediments which compose the crust of the earth, the animal kingdom had been at least three times entirely renovated; the secondary and tertiary periods having each been as clearly characterized by a distinct fauna as the primeval series. In the work on Russia the sequence was thus followed out truly, from the most ancient fossil-bearing strata to the most recent stages in the geological series.

tached to the term Silurian during the last ten years," which will indicate to him all my successive publications on this subject, including a geological map of England and Wales, published by the Society for the Diffusion of Useful Knowledge, in 1843. (Journal of Geol. Soc. Lond. vol. viii. p. 173. See also the memoir entitled, "On the meaning attached to the term 'Cambrian System,' and on the evidence since obtained of its being geologically synonymous with the previously established term 'Lower Silurian.'" — Journ. Geol. Soc. Lond. vol. iii. p. 165.) At the same time that I must protest against the recent proposal to absorb my Lower Silurian into his Cambrian Rocks, let me record my high estimation of the original memoirs of Professor Sedgwick, especially those on North Wales, Cumberland, and the adjacent counties, which stand upon their own intrinsic merits. The publication on the palæozoic fossils of the Cambridge Museum, which he is bringing out in conjunction with Professor M'Coy, will be, I doubt not, a lasting monument in the history of geological science. If that work had been published eighteen years ago, or in 1836, my friend, seeing that his Bala and my Llandeilo rocks were identical, might have proposed (although my fossils were first named and classified) that the Lower Silurian should be merged in the Cambrian. But, now that the terms Lower and Upper Silurian have been adopted in every country, the question is settled. My deep regret on the occasion of this difference of opinion has been expressed in the Preface; for in general views, as in private friendship, we are cordially united.